A Shot Parameter Specification Subsystem For Automated Control Of PBFA II Accelerator Shots*

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Abstract

The Shot Parameter Specification Subsystem (SPSS) is an integral part of the automatic control system developed for the Particle Beam Fusion Accelerator II (PBFA II) by the Control Monitor (C/M) Software Development Team [1]. This system has been designed to fully utilize the accelerator by tailoring shot parameters to the needs of the experimenters. The SPSS is the key to this flexibility.

Automatic systems will be required on many pulsed power machines for the fastest turnaround, the highest reliability, and most cost effective operation. These systems will require the flexibility and the ease of use that is part of the SPSS. The PBFA II control system has proved to be an effective modular system [2], flexible enough to meet the demands of both the fast track construction of PBFA II and the control needs of Hermes III at the Simulation Technology Laboratory. This system is expected to meet the demands of most future machine changes.

Introduction

On PBFA II, the C/M Software Development Team has designed and is implementing an automated control system. An integral part of the automated system is the Shot Parameter Specification Subsystem. A simplified overview of the interfaces between the machine operator, the subsystem control harware and the SPSS is shown in Fig. 1. The SPSS is a set of programs and touch panel terminals that allows the shot to be tailored easily and quickly to the needs of the experimenters. To accomplish the goal of full utilization, the PBFA II control system was conceived, designed, and implemented to operate a dynamic machine with operating

C/M System Block Diagram

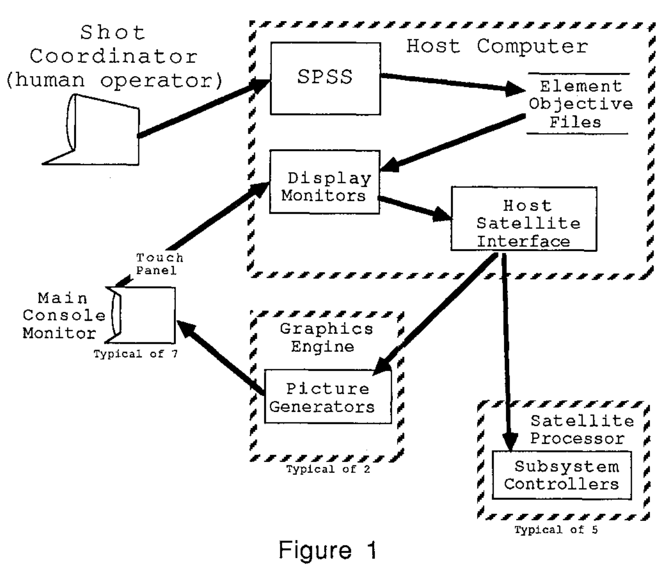

Figure 1

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procedures that will change throughout its life [3]. The SPSS design and implementation has to allow for this flexibility.

PBFA II is a multi-module, 100-TW accelerator designed to support experiments in Inertial Confinement Fusion. The experiments now being performed and scheduled on this accelerator range from simple ones to very complex ones. The shot parameters for experiments vary greatly; they include the number of modules used (1 to 36), power level used, and the number of subsystems involved. The setup time for a shot varies with the complexity of the experiment. Presently, a fully-instrumented 36-module diode shot requires one week of actual preparation. With a crew of ~65 required to do this setup, the concerns about reliability increase with the cost or time for a shot. In addition to experiments there is a continual need for specialized shots to diagnose machine failures, to test new components and subsystems, and to check out the machine changes before major experiments. These machine test shots may be single module shots with all the systems, all the modules of only one subsystem, or some combination. All of these shots, whether for experimenters or machine tests, require different configurations. Some only require minor modifications to machine parameters while others change or ignore whole sections of the machine. The C/M system has been designed to provide control for this wide range of activities.

As pulsed power experiments increase in complexity and number, the need for an automated control system has become apparent. This system must meet certain criteria to be effective. Automatic controls add complexity, and this complexity must be offset by flexibility, reliability, ease of operation, and ease of maintenance. A control system for PBFA II had to be flexible enough to meet the present and future requirments of experimental programs. The operation had to be simplified to the point that operators have time to think and evaluate the data. The maintenance must be simplifed by using modular design, good programming practice, and complete documentation. With these general criteria, the automated system built to operate PBFA II is adaptable to a wide variety of pulsed power machines.

SPSS Criteria

The SPSS was designed to meet the criteria that apply to the PBFA II system as a whole plus functional criteria that are generated by the users. Output from the SPSS is used by the Shot Coordinator (a person) and the subsystem controllers (software). The Shot Coordinator uses the SPSS to create, modify, and report shot specifications, i.e., parameters for setting up all accelerator subsystems. The SPSS provides the "commands" for the subsystem controller software per the shot specifications.

The subsystem controllers were implemented to meet the system criteria for modular design.

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14. ABSTRACT
The Shot Parameter Specification Subsystem (SPSS) is an integral part of the automatic control system developed for the Particle Beam Fusion Accelerator II (PBFA II) by the Control Monitor (C/M) Software Development Team [1). This system has been designed to fully utilize the accelerator by tailoring shot parameters to the needs of the experimenters. The SPSS is the key to this flexibility. Automatic systems will be required on many pulsed power machines for the fastest turnaround, the highest reliability, and most cost effective operation. These systems will require the flexibility and the ease of use that is part of the SPSS. The PBFA II control system has proved to be an effective modular system [2], flexible enough to meet the demands of both the fast track construction of PBFA II and the control needs of Hermes III at the Simulation Technology Laboratory. This system is expected to meet the demands of most future machine changes.

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These controllers are programs that control one subsystem or a part of a subsystem. Since the subsystem controllers often had to be written before the subsystems were complete (because of the fast track construction of PBFA II), they written and tested independent of specific hardware constraints. The command buffer was designed to hold subsystem characteristics and a command. Subsystem characteristics were gathered into a data base called the Machine Model Data Set (MMDS) as they became available. The MMDS forms a collection of facts that accurately models many of the limits of the accelerator: the highest voltage, the smallest unit of measurement, the time for a relay to respond, etc. This collection forms a database that has to be maintained. Therefore the SPSS must have available a set of database operations for creating, modifying, and listing the MMDS file. This requiremnt forms an auxiliary criterion.

The SPSS command buffer tells the controller to perfom a function and gives it the parameters required to complete the task. Before the subsystem controllers can use the command parameters and the subsystem characteristics, data must be converted from engineering units to units the machine understands and formatted. Analog input and output values are converted to millivolts, response times to milliseconds; digital inputs and outputs are transformed to 1's and 0's. Conversion and formatting of data to create a command buffer is a major functional criteria for the ease of use of the SPSS.

Subsystem controllers may operate in two modes: manual, where the operator commands individual components through the controller, or automatic, where the operator commands the controller to take the subsystem to a particular state or target value. In a manual mode the operator is responsible for reaching the target value or state, but in automatic mode the target values become the command parameters and are issued with the command. In both cases the target values must be known before either operator or controller starts a task.

On PBFA II the Shot Coordinator is responsible for setting the target values for each accelerator exercise. The second major functional criterion for the SPSS was to provide the Shot Coordinator with a tool to specify shot specification in as few parameters as possible. Many parameters can be derived from others or from the machine model once certain key parameters are known. These key parameters are incorporated into the Shot Objective File (SOF). The SOF contains parameters such as which modules are to be used and the charge voltage of the Marx generators, along with the shot identifier, title, and description. Early in the life of PBFA II the SOF parameter set is fairly large and includes Marx trigger system voltages, Marx generator charge voltage and current, gas switch pressures for both the Marx and rimfire switches, laser oscillator and preionizer voltages, and water resistivity. This parameter set will shrink and more parameters will be derived from the accelerator model as accelerator operating characteristics become better known. For example, the SF_6 gas pressure will be derived from the target charge voltage and the self-break curves for the Marx gas switches when they have been modeled as a system. The "intelligence" of the SPSS will increase as more of the accelerator subsystems are modeled. This intelligence reduces the number of parameters required in the shot specification and reduces the Shot Coordinator's burden for determining the proper shot parameters.

Human factors criteria are also important. Routine use by the Shot Coordinator requires that the SPSS be easy to use. Subsystem tasks are designed around a touch-screen terminal similar to touch screens on the control console. The human factors criteria extend to the placment of buttons and the format of messages displayed. The programs in the SPSS are designed so that keyboard use is minimized and, when it is used, the user has every opportunity to go back and correct mistakes.

Implementation

When the SPSS criteria were broken down into functional parts, programs were designed to perform these functions. One of the first functions identified was the human interface. We decided to use a touch panel terminal because the operators were already familar with touch screens in use on the main control panel. The touch panel on the terminal we decided to use (an HP 150 with touch-screeen accessory) had very little software written to handle the touch-panel used as a terminal. A group of touch-panel handling routines was designed and implemented. These routines are written in a standard Fortran 77 and are portable to almost any computer. These routines are general so that the same routine produces many different screens depending on the parameters passed to it.

We identified several functions that were logically grouped into programs. These are the Shot Objective Specification Interface (SOSI), the Model Based Objective Generator (MBOG), and Set_Knobs. A short description of each program and a simplified flow diagram for the major program units is given below in the SPSS Program Table, Fig. 2.

The SOSI program was given the job of getting the shot objectives from the Shot Coordinator, verifing the parameters, and creating the Shot Objective File (SOF). In order to keep the SOSI program as general as possible, it reads a configuration file. The configuration file is created for each shot type (e.g., Marx dummy load) and lists the required parameter set. The SOSI program prompts the Shot Coordinator for only the required parameters for that shot type. Then the SOSI verifies the given parameters against machine limits recorded in the Machine Model Data Set and creates the SOF. The SOF stores the parameters as real numbers with associated engineering units, the description and title as character strings, and module and subsystem choices as logical arrays. The SOF is an indexed file written to only once but read several times. The indexing allows the file structure to be decoupled from the data that is stored. Therefore, as the SOF parameter list expands or shrinks, the programs that access the SOF will not have to be changed.

The Model Based Objective Generator (MBOG) creates the command buffers for each of the subsystem controllers. The command buffer is made up of three parts: address and mode information, target values, and subsystem characteristics. Target values come from the SOF, subsystem characteristics from the MMDS, and address and mode are preset for the

SPSS Program Table

Program	Function
SOSI	The Shot Objective Specification Interface allows the Shot Coordinator to create or edit a Shot Objective File (SOF) that holds the shot parameters for one shot.
MBOG	The Model Based Objective Generator creates the Subsystem command buffers from the SOF (shot spec) and the MMDS (Machine Model Data Set). The command buffers are stored as Element Objective Files (EOF'S). Each EOF holds the parameters for one subsystem.
Set_Knobs	Prepares the computer for a shot according to the shot specification. It creates the file struture to hold the shot data and sets the machine to the idle/prep state.
MDSED	Machine Data Set Editor allows authorized persons to edit the Machine Model Data Set (MMDS).
SQMGR	Shot Queue Manager allows the creation of multiple shot specifications (SOF and EOF's) and allows the user to manipulate their order in the queue.
RPGEN	The Report Generator formats the SOF(shot specs) and EOF's (Subystem command buffers) per the user's request.
SMCI	Shot Master Command Interface controls user access to the other programs and provides the entry point to the SPSS system.

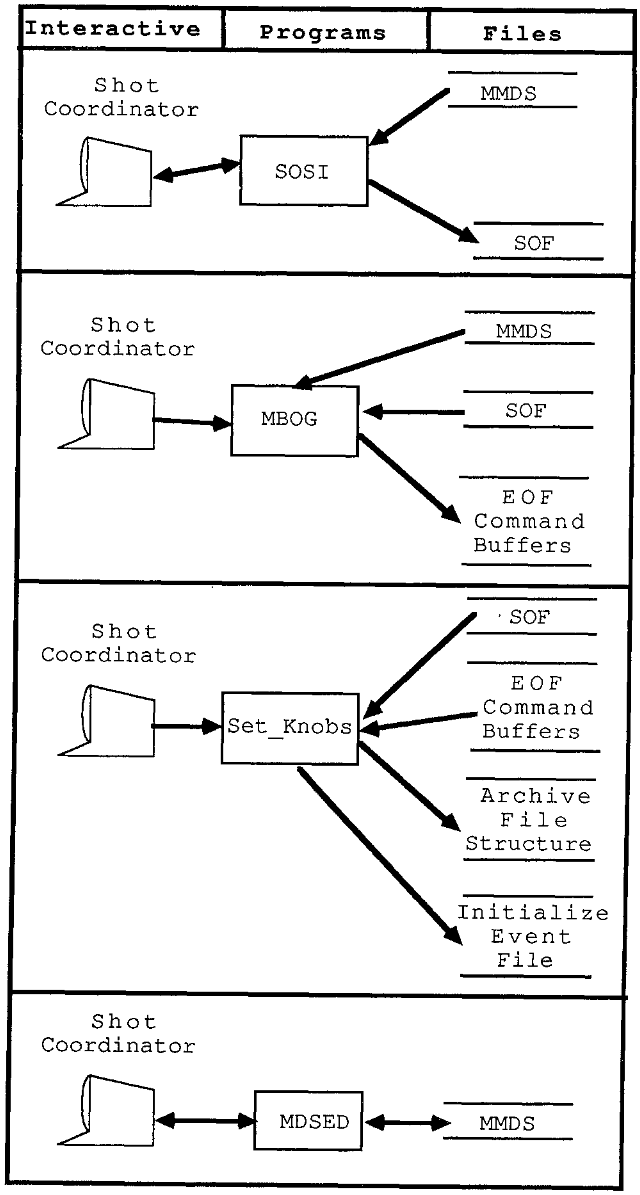

Figure 2

controller that is being commanded. The command buffer is encoded for use by the subsystem controllers. The MBOG takes values from various sources and converts some of them for direct use, but it also derives values that are required by the subsystem controller. For example, the target voltage for the Marx Charge is given in the SOF, but the high and low limits for an acceptable shot are derived from the target voltage and the tolerance percentages stored in the MMDS.

The program Set_Knobs is the bridge between the SPSS and the rest of the control system. Set_Knobs creates a directory structure for the shot data to be recorded. The SOF and command buffers for that shot are transferred into that structure. The control system uses a global file called the "event file" to find the shot number and the command buffers. The shot specification also tells which subsystem controllers are going to be active on a shot. This information is also placed in the event file. Each of the controllers uses the shot directory to file the data they record. Subsystem controllers also use the event file to record their start and end times. Set_Knobs must confirm that the current shot is finished and the machine is in the idle/prep state before it changes the event file. But, if a mistake has been made, Set_Knobs can also command the control system to take the machine to an idle/prep state in order to correct the problem setup for the next shot.

Using SPSS

A typical procedure for a shot setup follows. The Shot Coordinator sits down at the terminal, and the first screen he sees is the Shot Master Command Interface (SMCI) that allows him to choose one of the SPSS programs. The normal sequence will be to run the SOSI to create the specification, the MBOG to create the command buffers, then Set_Knobs to set up the machine for the next shot. If the Shot Coordinator wants to set up a series of shots, he would repeatedly use the SOSI. These multiple specifications are placed in a first-in first-out queue for him by the Shot Queue Manager (SQMGR). This feature allows him to set up these specifications ahead of time. The command buffers may also be created for these queued shots. Since Set_Knobs only operates on the first shot in the queue and SOSI only adds a shot to the end of the queue, a method of manipulating the queue is needed. The Shot Coordinator can use the SQMGR to reorder the queue or to delete shots that are pending in the queue. To get a listing of the parameters for pending or past shots, the Shot Coordinator would use RPGEN, the report generator, to list shot parameters and command buffers (appropriately decoded). When there is a hardware change in the machine, the MMDS will be affected. For example, the machine tolerances for the charge voltage have changed due to a new charging power supply. The Shot Coordinator uses the Model Data Set Editor (MDSED) to make the changes in the MMDS. He may easily page through the file by touching the page control button; touch the value he wishes to change; then using the touch panel keypad that appears, make the changes.

Conclusions

The SPSS is a valuable tool in operating PBFA II, and it is easy to use and maintain. Parts of the SPSS could be implemented on other facilities, tailored to their needs. And, because of its modular design, the whole system does not have to be implemented. For example, the C/M Software Design Team on the Hermes III project have transported the touch-screen handling routines and the command buffer generating modules for their use. The flexibility designed into the C/M system has not been limited by the SPSS and does allow the operators to more easily configure the accelerator for whatever the experimenter needs.

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References

1. V. M. Italiano, "Providing Automated Control For PBFA II", 5th IEEE Pulsed Power Conference, June 1985, pp.376.
2. Control/Monitor Team, "PBFA II Control/Monitor System Initial Design", Unpublished Sandia Internal Report, March 1984.
3. S. Y. Goldsmith, "C/M Version 2 Prototype Specification", Unpublished Sandia Internal Document, March 1986